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Sir:

Transmitted herewith for filing is the
patent application of:

Inventor: Stephen M. Clark, Terry J. Golubiewski and Scott J.F. Zogg
For: Synchronization Technique For Spread Spectrum Frequency Hopped Data Links And Radios
Using The Same
Doc. No.: 99CR074/KE

Enclosed are:

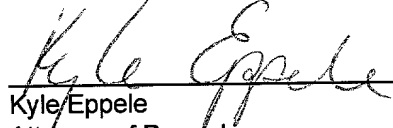
- ☒ 5 Sheets of Drawings.
- ☒ An Assignment of Invention to Rockwell Collins, Inc., Cedar Rapids, IA 52498.
- ☒ Combined Declaration and Power of Attorney.
- ☒ Information Disclosure Statement and references.

Claims as Filed

For	Number Filed	Number Extra	Rate	Base Fee	\$ 690.00
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Ind. Claims	3 - 3	0	X \$78		\$ 0.00
Total Filing Fee					\$690.00

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Respectfully submitted,



Kyle Eppele
Attorney of Record
Reg. No. 34,155

ROCKWELL COLLINS, INC.
Intellectual Property Department
400 Collins Road NE M/S 124-323
Cedar Rapids, IA 52498
Telephone: (319) 295-8280
Facsimile No. (319) 295-8777


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U.S. PTO
709-560381
04/28/00

PATENT
99CR074/KE

U.S. PATENT APPLICATION
FOR
SYNCHRONIZATION TECHNIQUE FOR SPREAD
SPECTRUM FREQUENCY HOPPED DATA LINKS AND
RADIOS USING THE SAME

BY

STEPHEN M. CLARK,
TERRY J. GOLUBIEWSKI,
AND
SCOTT J.F. ZOGG

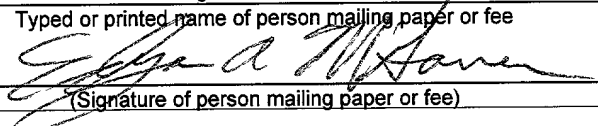
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BACKGROUND OF THE INVENTION

Frequency hopped/direct sequence spread spectrum (FH/DSS) time division multiple access (TDMA) data links (hereafter FH/DSS data links) require synchronization to operate correctly. Often, this synchronization is achieved in phases. In each phase a higher level of synchronization is achieved. The lowest level of synchronization, sometimes referred to "coarse synchronization", refers to synchronization on the order of magnitude of one of the TDMA time slots that are shared by all users of the network. The coarse synchronization is typically followed by a fine synchronization stage. Frequently, the time required for coarse synchronization is the major contributor to the total synchronization time.

Coarse synchronization usually requires an initial estimate of time before synchronizing to the correct slot of the network. In currently available FH/DSS data links, time required to acquire coarse synchronization is on the same order of magnitude as the accuracy of the initial time estimate. For example, for an initial time accuracy of one minute σ , a radio would require on the order of one to five minutes to acquire coarse synchronization.

Previously available techniques for obtaining coarse synchronization involved tuning a correlation devise for a specific direct sequence pattern, and dwelling until a receive bit sequence with a high correlation is obtained. This process requires a length of time which is longer than the standard deviation of the initial time uncertainty.

Another available method of obtaining coarse synchronization requires the transmitter to go into a

transmit mode in which a trivial signal is transmitted for the purpose of gaining coarse synchronization. This method has the inherent vulnerability of being susceptible to jamming and spoofing, and requires cooperation by the transmitter. Thus, in data link systems operating in certain environments, this can be a highly undesirable solution.

Solutions for synchronization to a FH/DSS data link generally fall into two models, serial-search acquisition and matched-filter acquisition. See for example PRINCIPLES OF SECURE COMMUNICATION SYSTEMS, pp. 148-173 (Artech House 1992) by Don J. Torrieri; and SPREAD SPECTRUM COMMUNICATIONS HANDBOOK, Ch. 3 pp. 956-991 (McGraw-Hill 1994) by Simon et al. which are herein incorporated by reference in their entirety. Serial-search acquisition requires the received signal to be mixed against a local version of the frequency hopping pattern. The down converted signal is then low-pass filtered and integrated for a period. If the received energy exceeds a threshold, synchronization is declared. If not, the local frequency hopping pattern is shifted in time and the process starts over. For modern data links, serial-search acquisition is often too slow. Likewise, matched-filter acquisition as described in the Torrieri reference requires longer than the initial time uncertainty as discussed above.

Consequently, a faster method of performing coarse synchronization in a FH/DSS data link when a user has poor knowledge of time (minutes) is needed.

SUMMARY OF THE INVENTION

A method of obtaining coarse synchronization in a frequency hopped/direct sequence spread spectrum (FH/DSS) time division multiple access (TDMA) data link network includes tuning the receiver to a first frequency used in the data link network. Then, signal strength of signals received on the first frequency during a sample time period is observed to obtain a sample energy pattern. An expected energy pattern during a time uncertainty window is determined based upon a known hopping pattern. Then, the sample energy pattern is compared to a first portion of the expected energy pattern, with the first portion of the expected energy pattern corresponding to a first time period within the time uncertainty window. A determination is then made as to whether the first time period is a coarse synchronization candidate based upon the comparison. If it is determined that the time period is a coarse synchronization candidate, one or more additional comparisons on different frequencies can be used to verify the hypothesis.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic illustration of a FH/DSS data link radio network having radios which obtain coarse synchronization using methods of the present invention.

FIG. 2 is a block diagram illustrating a radio which is programmable to obtain coarse synchronization in accordance with the methods of the invention.

FIGS. 3A and 3B are diagrammatic illustrations of a general format in which TDMA time slots can be organized, both in the prior art and in the present invention.

FIGS. 4A-4C are plots illustrating steps used to obtain a sample pattern on a frequency in the FH/DSS data link radio network.

FIG. 5 is a plot illustrating an expected pattern corresponding to a time uncertainty window which is determined based upon a known hopping pattern.

FIGS. 6A-6C are plots illustrating comparisons, of the sample pattern against portions of the expected pattern, which can be used to identify coarse synchronization time candidates.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

FIG. 1 is a diagrammatic illustration of a FH/DSS data link or radio network 100. Network 100 includes a multiplicity of radios 105, which are adapted to communicate using FH/DSS TDMA techniques of the type known in the art. The FH/DSS data link radios 105 (radios 105A-105F are shown but more or less can be included) can communicate, using known techniques, with selected ones of the other radios in network 100, or with all of the other radios in network 100. For example, as illustrated in FIG. 1, radio 105A can be set up to transmit messages to and receive messages from radio 105D. As shown, radio 105C is set up to transmit messages to and receive messages from both of radios 105B and 105F. Also, as illustrated, radio 105B can be used in a broadcast mode in which it transmits messages simultaneously to each of radios 105A, 105C, 105D, 105E and 105F. The illustrated configuration of network 100 is provided as an example of an operating environment, and is not intended to limit the invention.

Each of radios 105 in network 100 communicates in a coordinated manner during TDMA time slots over a multiplicity of different frequencies according to a frequency hopping pattern. The frequency hopping pattern used in the system is a pseudo-noise (PN) based sequence, where the PN is dependent upon the system time. In accordance with the present invention, radios 105 are adapted to obtain coarse synchronization by observing a portion of the frequency hopping pattern, and subsequently searching all known hop patterns within a time window to find the one that best correlates. This and other features of the present invention are discussed below.

FIG. 2 is a block diagram illustrating a typical configuration for each of radios 105 in network 100. The invention is not limited to the particular implementation of radio 105 shown in FIG. 2. In the exemplary embodiment shown in FIG. 2, each radio 105 includes an antenna 205, receive/transmit circuitry 210, signal strength determining circuitry 215, digital baseband processing circuitry 220 and a user input/output (I/O) 225. Antenna 205 and receive/transmit circuitry 210 are used to transmit digital data to other radios within network 100 during TDMA time slots over the multiplicity of frequencies according to a hopping pattern. Digital baseband processing circuitry 220, which is for example a suitably programmed microprocessor or digital signal processor, controls receive/transmit circuitry 210 in order to transmit digital information over the network according to the hopping pattern. Digital base band processing circuitry 220 also processes digital data received by antenna 205 and circuitry 210 from other radios within network 100.

Signal strength determining circuitry 215 can be implemented at least partially within a microprocessor such as the same microprocessor used to implement digital baseband processing circuitry 220. Signal strength determining circuitry 215 is used in accordance with the invention to determine the signal strength of signals received by antenna 205 and circuitry 210. In this manner, radio 105 can observe a portion of the frequency hopping pattern used by the other radios, and then can search all known hop patterns within a time window to find the one that best correlates, thereby providing a mechanism for performing coarse synchronization.

FIGS. 3A and 3B diagrammatically illustrate the general format in which TDMA time slots are organized, both in the prior art and in the present invention. As illustrated in FIG. 3A, in a TDMA frequency hopping communication network, the radios transmit and receive during segmented time periods sometimes referred to as "slots". A multiplicity of slots 310 (N slots are illustrated in FIG. 3A) together form a period of time commonly referred to as a "frame" 305. As shown in FIG. 3B, a multiplicity of frames 305 (M frames are illustrated in FIG. 3B) together form a larger time period known as an "epoch" 320. The present invention includes a method of performing coarse synchronization to a particular slot 310 in a manner which is orders of magnitude faster than conventional methods.

As discussed above, if the frequency hopping pattern used in the network is a PN based sequence, where the PN is dependent on the system time and therefore on the particular time slots, synchronization can be obtained by observing a portion of a frequency hopping pattern, and then searching all known hop patterns within a time window to find the one that best correlates. The time window in which all known hopping patterns are searched includes multiple time slots, and for example, could be on the order of 0.25 seconds in length. With the methods of the present invention which implement the search process faster, the result is a coarse synchronization with the transmitter after only a very brief search. Typically, the search requires a time which is much less than the duration of the time uncertainty window. The time uncertainty window represents a time quantity that the radio clock is estimated to be off by as compared to the

time used by other radios in the network. In an exemplary embodiment, the time uncertainty window can be on the order of about one second or more. Generally, using the methods of the present invention, coarse synchronization times can be improved by one to two orders of magnitude.

Aspects of the coarse synchronization technique of the present invention can be described as follows. Ideally, the method of the present invention operates under the assumption that the frequency-hopping pattern is a PN sequence, where each frequency is picked with an approximately equal probability of occurrence. The first step in the process of obtaining coarse synchronization is to tune the receiver (e.g., antenna 205 and circuitry 210) of a radio 105 to a fixed frequency and to observe the received signal strength (energy) versus time over some period. Thus, signal strength determination circuitry 215 is utilized at this point of the process. During this time, samples of the power received on the tuned frequency are collected. FIG. 4A illustrates a sample 405 of the collected power received on the tuned frequency over a sample period of time T_{SAMPLE} .

After collecting sample 405, a processing element (e.g., digital base band processing circuitry 220) computes a threshold value 410 that statistically only a fraction of the samples exceed. This is illustrated in FIG. 4B. The result is a sample 415 of received energy during the sample time period T_{SAMPLE} which is more clearly representative of transmissions on the network, and which is less effected by noise. This is illustrated in FIG. 4C.

After applying threshold 410 to the energy received on the tuned frequency during the sample period T_{SAMPLE} to

obtain energy sample 415, the processor element tries to correlate the received energy versus time with known hopping patterns for each slot in the uncertainty window until a correlation is found. An exemplary expected energy pattern 505, for a known hopping pattern corresponding to the time uncertainty window, is illustrated in FIG. 5. The pattern shown in FIG. 5 is for illustrative purposes only, and is not necessarily indicative of an expected energy pattern during an uncertainty window using actual hopping patterns. Likewise, FIGS. 4A-4C and 6A-6C are illustrative, but not intended to limit the invention.

Correlation of the received energy versus time with the known hopping patterns for each slot in the uncertainty window is done by first assuming a start time and computing the hop pattern for that time. For example, in FIG. 6A hop pattern 605 for an initial start time is shown between dashed lines 606 and 607. At all the positions in the computed hop pattern 605 where the received frequency was tuned, the received energy in sample 415 is compared to the expected hop pattern 605.

If the energy in the received pattern 415 is higher than threshold 410 (FIG. 4B) at each expected time in hop pattern 605 (i.e., if sample pattern 415 matches expected hop pattern 605), the corresponding initial time assumption is noted as a possibility for the coarse synchronization time. If the energy level in received pattern 415 does not exceed threshold 410 at each of the expected times (i.e., if pattern 415 does not match expected pattern 605), then the hopping pattern is shifted ahead by one sample time, and is again compared to check for a correlation. This is shown for example in FIG. 6B

in which the expected energy hopping pattern 610 for a second time is computed.

Expected energy hopping pattern 610 is shown between dashed lines 607 and 611. Received energy pattern 415 is compared to expected hopping pattern 610 to identify a possible energy correlation. This correlation process is repeated over the entire window of time uncertainty until a match or high correlation is found. For example, FIG. 6C illustrates expected energy hopping pattern 615, between dashed lines 611 and 616, for a third period of time. As can be seen in FIG. 6C, received energy pattern 415 matches expected energy hopping pattern 615, indicating that this third time period is a good candidate for coarse synchronization. If no correlation is found, the procedure is repeated on another frequency.

After finding a potential correlation, a number of test correlations may be performed on another frequency, where a block of samples are taken and the pattern is compared to the appropriate hopping pattern for the new coarse synchronization time hypothesis. If the new block of samples on a different frequency also correlates the time is used as the coarse synchronization time. This verification process is beneficial in some embodiments because, in a jammed environment, a pulsed jammer or other jammer can cause a number of time hypotheses to pass the initial criteria. However, false hypotheses may be statistically disproved very quickly.

This coarse synchronization process may be further refined by first examining all channels (frequencies), and only using those channels whose background energy is lowest. This helps the desired transmit pulses to appear above the noise in a partial band jammed environment.

An illustration of the decreased coarse synchronization time which can be achieved using the invention is provided as follows. To estimate the capabilities of current technologies for performing the computations described above, an assumption can be made that there is a single transmitter in the network transmitting in sixteen known slots per second. Each transmission can be assumed to be on 258 different frequencies, randomly chosen from the available frequencies for the network. Tuning to a particular frequency for a one second interval, that frequency can be expected to be visited on average about 81 times. If the time uncertainty window were for example 60 seconds long, and if the samples had a length of about 13 microseconds, there would be 4,615,384 possible alignments of the received one second period with respect to the 60 second uncertainly window. Using a 200 MHz TMS320C6201 DSP, the received data can be compared for correlation against each of the possible alignments in less than one second. If the threshold is set so that 80% of the samples pass the threshold, the probability of a noise source causing a correlation is less than one in sixteen for the entire uncertainty window. This is a low enough probability to allow investigation of every correlation that is found using the method described above. Through this process, synchronization can be gained in less than two seconds, whereas using conventional synchronization techniques the assumed sixty second uncertainty window would have required on the order of sixty seconds to achieve coarse synchronization. For larger time uncertainties, the synchronization time reduction is an even greater multiple.

In another embodiment, each of multiple receivers 105 is tuned to a different frequency, and is used to obtain a different sample pattern during the sample time period. The process described above is then used to compare each of the sample energy patterns from the different operational frequencies to the expected energy patterns on those frequencies (as determined using the hopping pattern). This provides additional information, and among other benefits, may eliminate the need for further verification of a synchronization candidate.

Although the present invention has been described with reference to illustrative embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

CLAIMS

What is claimed is:

1. A method of obtaining coarse synchronization in a frequency hopped/direct sequence spread spectrum (FH/DSS) time division multiple access (TDMA) data link network, the method comprising:
 - tuning a first receiver to a first frequency out of a plurality of frequencies used in the data link network;
 - observing signal strength of signals received on the first frequency during a sample time period to obtain a sample energy pattern;
 - determining an expected energy pattern corresponding to a time uncertainty window, the expected energy pattern being based upon a known hopping pattern;
 - comparing the sample energy pattern to a first portion of the expected energy pattern, the first portion of the expected energy pattern corresponding to a first time period within the time uncertainty window; and
 - determining whether the first time period is a coarse synchronization candidate as a function of the comparison between the sample energy pattern and the first portion of the expected energy pattern.

2. The method of claim 1, wherein observing signal strength of signals received on the first frequency during the sample time period to obtain the sample energy pattern further comprises:

obtaining a received energy pattern by observing the signal strength of the signals received on the first frequency during the sample time period;
comparing the received energy pattern to a threshold;
and
obtaining the sample energy pattern by eliminating energy components from the received energy pattern which do not exceed the threshold.

3. The method of claim 1, wherein the first time period corresponds to a first plurality of time slots used in the data link network and which fall within the time uncertainty window, and wherein determining the expected energy pattern further comprises determining the first portion of the expected energy pattern based upon an expected hopping pattern for the first plurality of time slots.

4. The method of claim 3, wherein the sample period has a duration which is substantially equal to the first time period which falls within the time uncertainty window.

5. The method of claim 1, wherein determining whether the first time period is a coarse synchronization candidate further comprises determining whether the sample energy pattern and the first portion of the expected energy pattern are substantially a match.

6. The method of claim 1, and if the first time period is determined to not be a coarse synchronization candidate, then further comprising:

comparing the sample energy pattern to a next portion of the expected energy pattern, the next portion of the expected energy pattern corresponding to a next time period within the time uncertainty window; and

determining whether the next time period is a coarse synchronization candidate as a function of the comparison between the sample energy pattern and the next portion of the expected energy pattern.

7. The method of claim 6, and further comprising sequentially repeating, for subsequent time periods within the time uncertainty window until a coarse synchronization candidate is found, the step of comparing the sample energy pattern to the next portion of the expected energy pattern, and the step of determining whether the next time period is a coarse synchronization candidate as a function of the comparison.

8. The method of claim 7, and after a coarse synchronization candidate is found, then further comprising:

tuning the first receiver to a second frequency out of the plurality of frequencies used in the data link network;

observing signal strength of signals received on the second frequency during a second sample time period to obtain a second sample energy pattern;

determining a second expected energy pattern during a time period corresponding to the second sample time period, using the coarse synchronization candidate as a reference time, based upon the known hopping pattern;

comparing the second sample energy pattern to the second expected energy pattern corresponding to the second sample time period; and

verifying the accuracy of the coarse synchronization candidate based upon the comparison between the second sample energy pattern and the expected energy pattern.

9. The method of claim 1, and further comprising:
tuning each of a plurality of other receivers to
different ones of a plurality of other
frequencies used in the data link network;
observing signal strength of signals received on each
of the plurality of other frequencies during the
sample time period to obtain a plurality of
other sample energy patterns;
determining a plurality of other expected energy
patterns corresponding to the time uncertainty
window, each of the plurality of other expected
energy patterns being based upon a known hopping
pattern and upon a corresponding one of the
plurality of other frequencies;
comparing each of the plurality of other sample
energy patterns to a first portion of the
corresponding one of the plurality of other
expected energy patterns, the first portion of
each of the plurality of other expected energy
patterns corresponding to a time period within
the time uncertainty window; and
determining whether the time period within the time
uncertainty window is a coarse synchronization
candidate as a function of the comparisons.

10. A radio for use in a frequency hopped/direct sequence spread spectrum (FH/DSS) time division multiple access (TDMA) data link network, the radio comprising:

a first receiver adapted to be tuned to a first frequency out of a plurality of frequencies used in the data link network;

signal strength determining circuitry adapted to observe signal strength of signals received on the first frequency during a sample time period;

processing circuitry coupled to the signal strength determining circuitry and adapted to determine a sample energy pattern in response to the observations by the signal strength determining circuitry, the processing circuitry being further adapted to determine an expected energy pattern corresponding to a time uncertainty window, the expected energy pattern being based upon a known hopping pattern, the processing circuitry being adapted to compare the sample energy pattern to a first portion of the expected energy pattern, the first portion of the expected energy pattern corresponding to a first time period within the time uncertainty window, the processing circuitry further being adapted to determine as function of the comparison whether the first time period is a coarse synchronization candidate.

11. The radio of claim 10, wherein the processing circuitry is further adapted to:

obtain a received energy pattern by observing the
signal strength of the signals received on the
first frequency during the sample time period;
compare the received energy pattern to a threshold;
and
determine the sample energy pattern by eliminating
energy components from the received energy
pattern which do not exceed the threshold.

12. The radio of claim 1, wherein the first time period corresponds to a first plurality of time slots used in the data link network and which fall within the time uncertainty window.

13. The radio of claim 12, wherein the sample period has a duration which is substantially equal to the first time period.

14. The radio of claim 10, wherein if the first time period is determined to not be a synchronization candidate, then the processing circuitry is further adapted to compare the sample energy pattern to a next portion of the expected energy pattern, the next portion of the expected energy pattern corresponding to a next time period within the time uncertainty window, and wherein the processing circuitry is adapted to determine whether the next time period is a coarse synchronization candidate as a function of the comparison between the sample energy pattern and the next portion of the expected energy pattern.

15. An apparatus for obtaining coarse synchronization in a frequency hopped/direct sequence spread spectrum (FH/DSS) time division multiple access (TDMA) data link network, the apparatus comprising:

means for tuning a first receiver to a first frequency out of a plurality of frequencies used in the data link network;

means for observing signal strength of signals received on the first frequency during a sample time period to obtain a sample energy pattern;

means for determining an expected energy pattern corresponding to a time uncertainty window, the expected energy pattern being based upon a known hopping pattern;

means for comparing the sample energy pattern to a first portion of the expected energy pattern, the first portion of the expected energy pattern corresponding to a first time period within the time uncertainty window; and

means for determining whether the first time period is a coarse synchronization candidate as a function of the comparison between the sample energy pattern and the first portion of the expected energy pattern.

**SYNCHRONIZATION TECHNIQUES FOR SPREAD
SPECTRUM FREQUENCY HOPPED DATA LINKS AND
RADIOS USING THE SAME**

ABSTRACT OF THE DISCLOSURE

A method of obtaining coarse synchronization in a frequency hopped/direct sequence spread spectrum (FH/DSS) time division multiple access (TDMA) data link network includes tuning the receiver to a first frequency used in the data link network. Then, signal strength of signals received on the first frequency during a sample time period is observed to obtain a sample energy pattern. An expected energy pattern during a time uncertainty window is determined based upon a known hopping pattern. Then, the sample energy pattern is compared to a first portion of the expected energy pattern, with the first portion of the expected energy pattern corresponding to a first time period within the time uncertainty window. A determination is then made as to whether the first time period is a coarse synchronization candidate based upon the comparison. If it is determined that the time period is a coarse synchronization candidate, one or more additional comparisons on different frequencies can be used to verify the hypothesis.

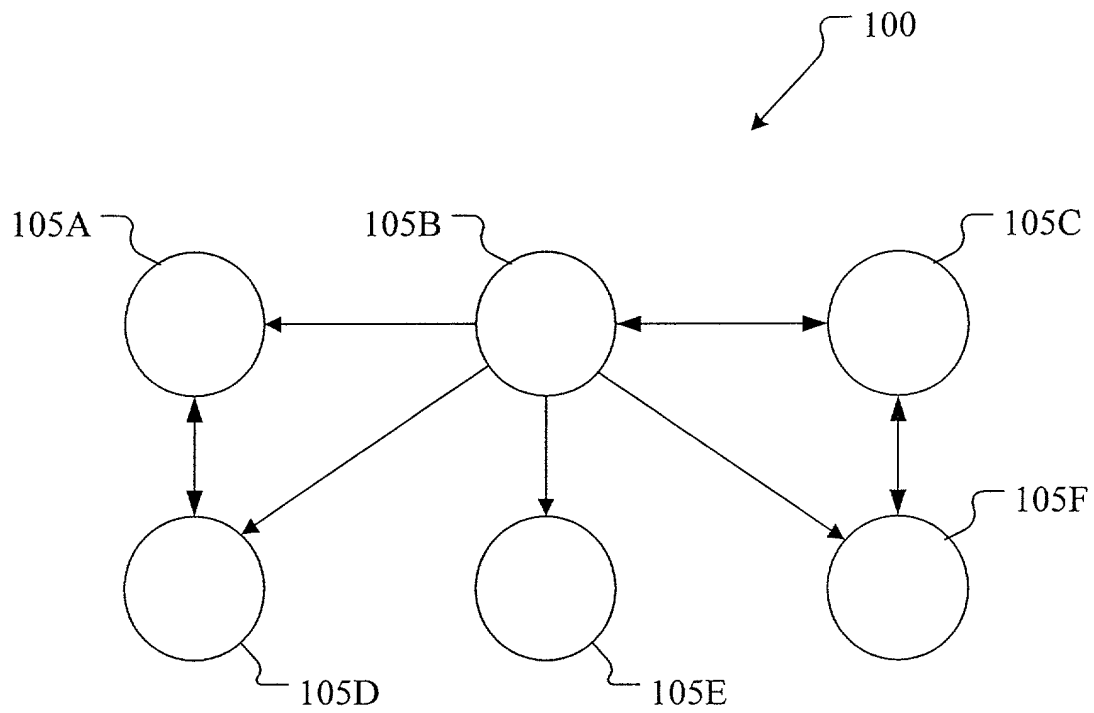


FIG. 1

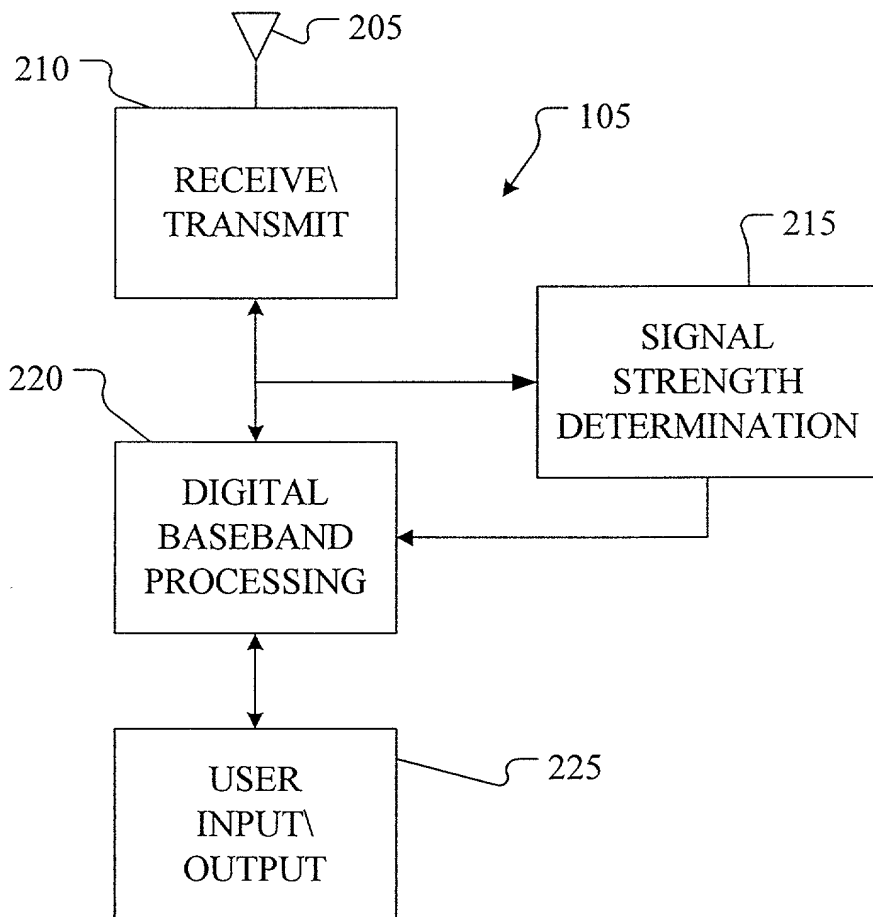


FIG. 2

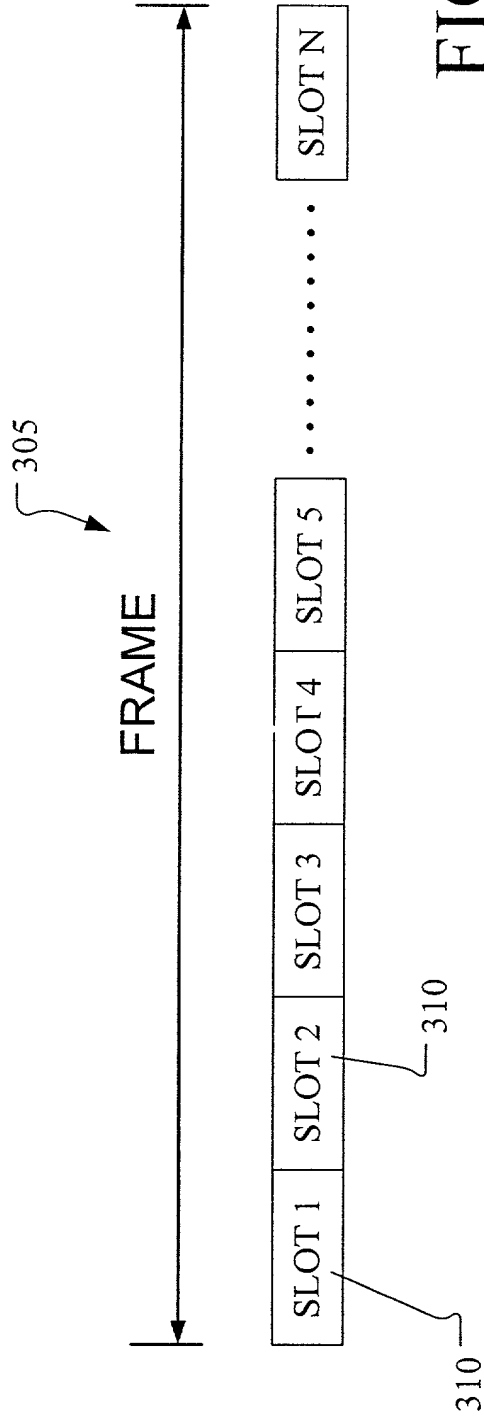


FIG. 3A

PRIOR ART

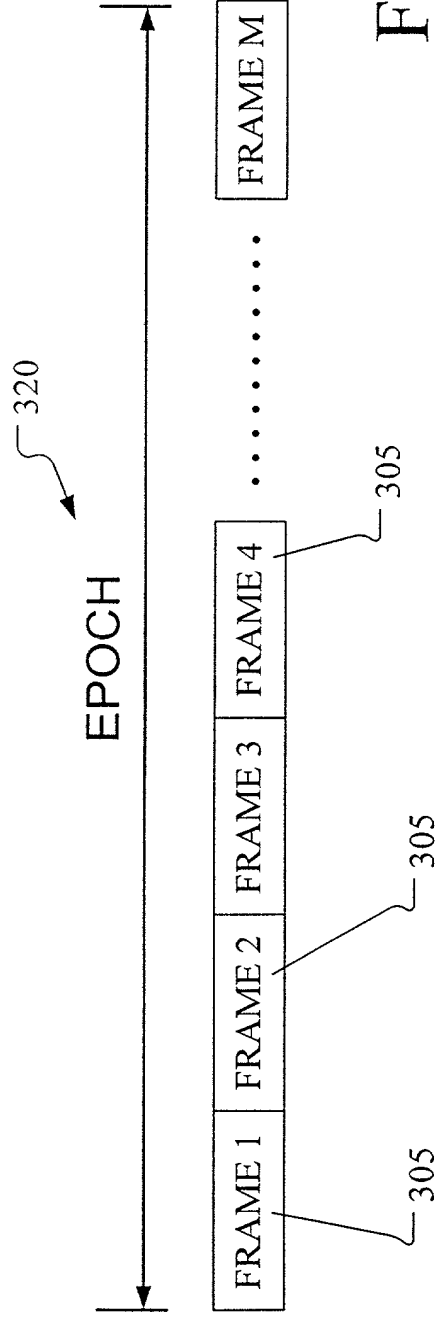


FIG. 3B

PRIOR ART

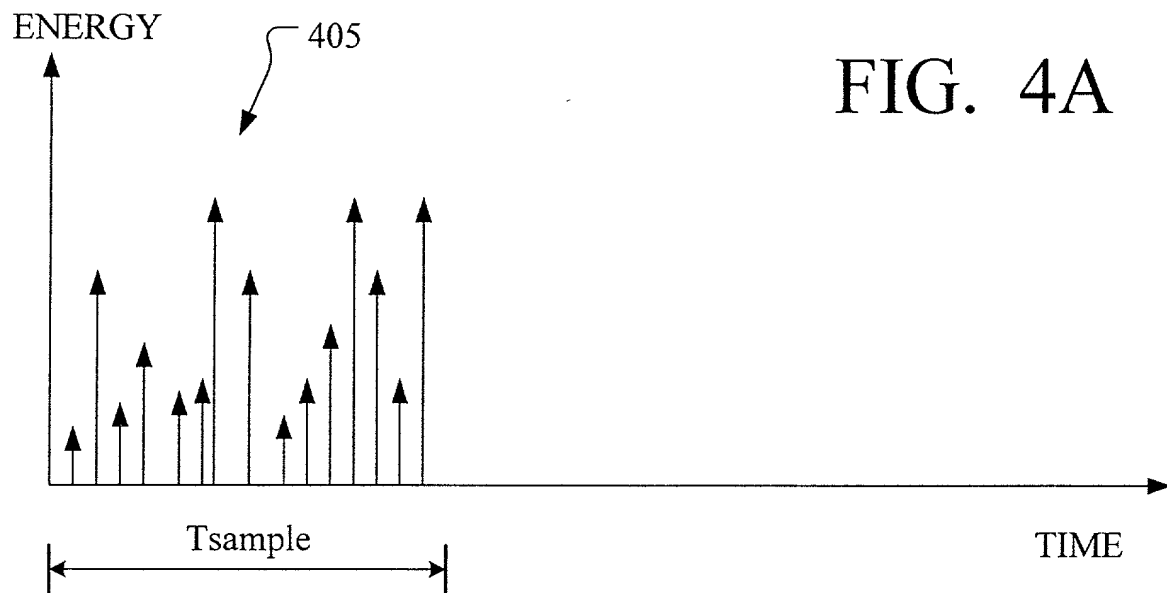


FIG. 4A

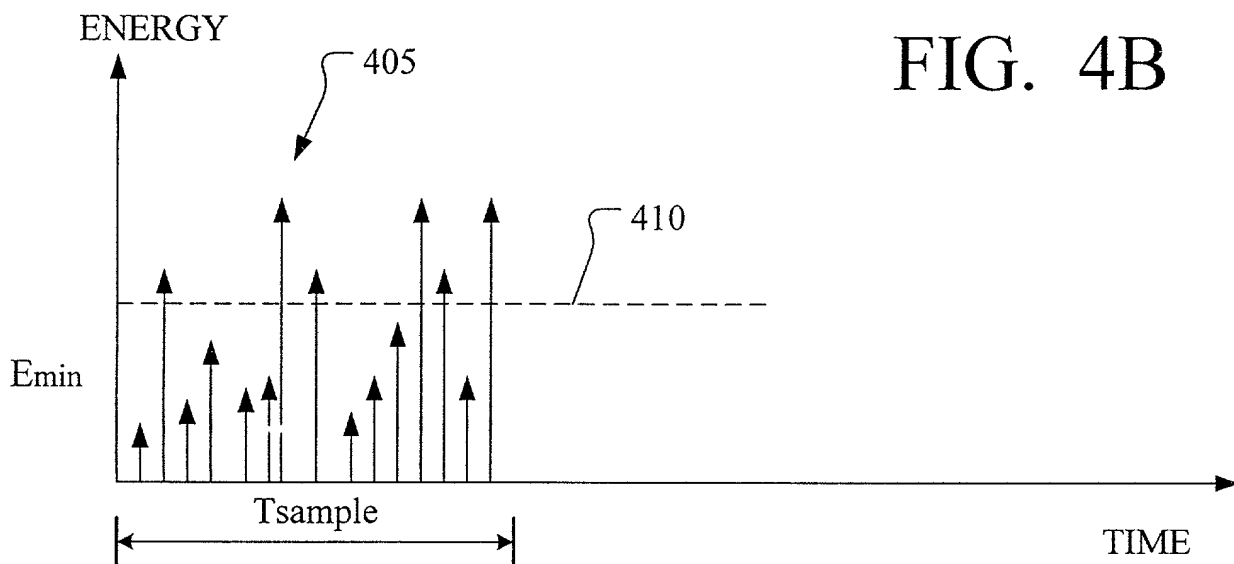


FIG. 4B

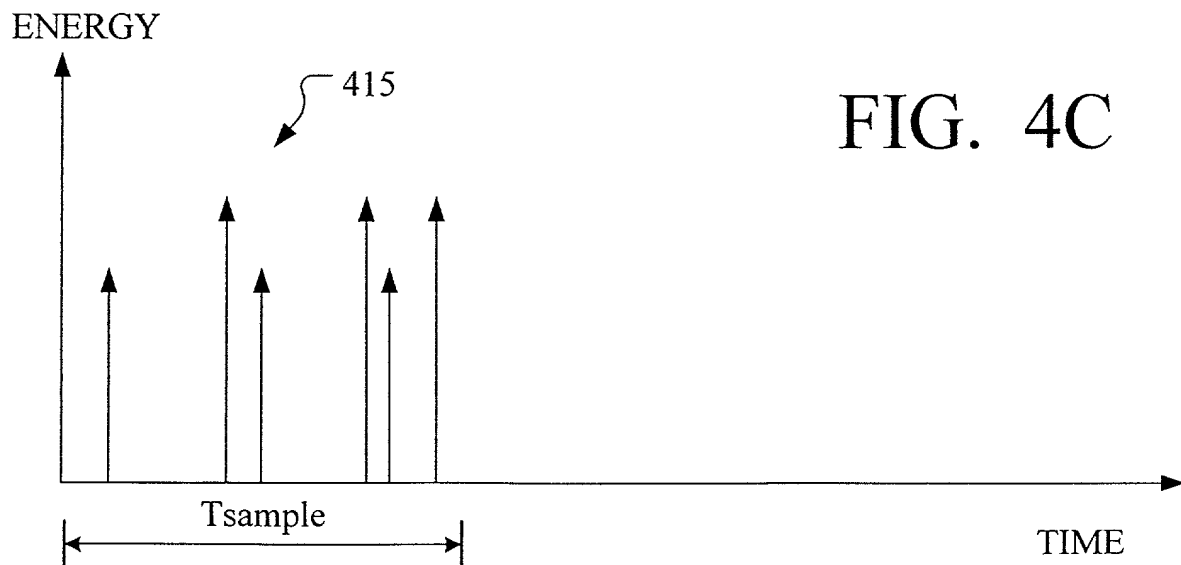


FIG. 4C

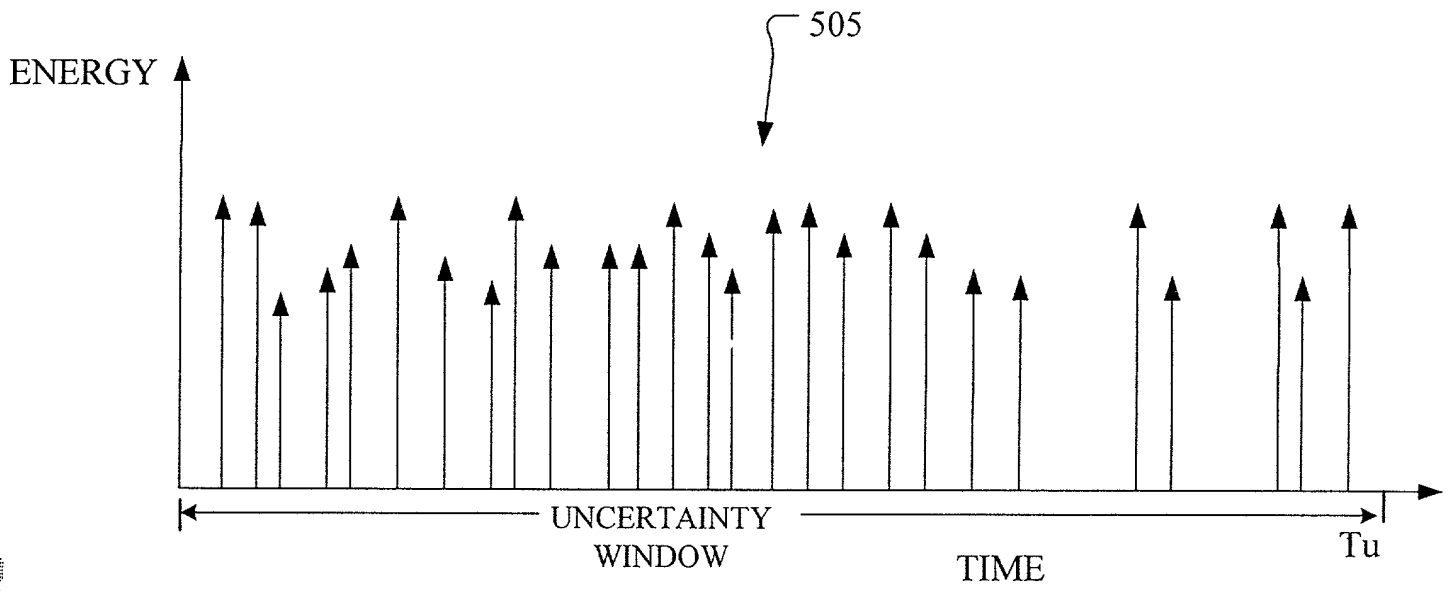


FIG. 5

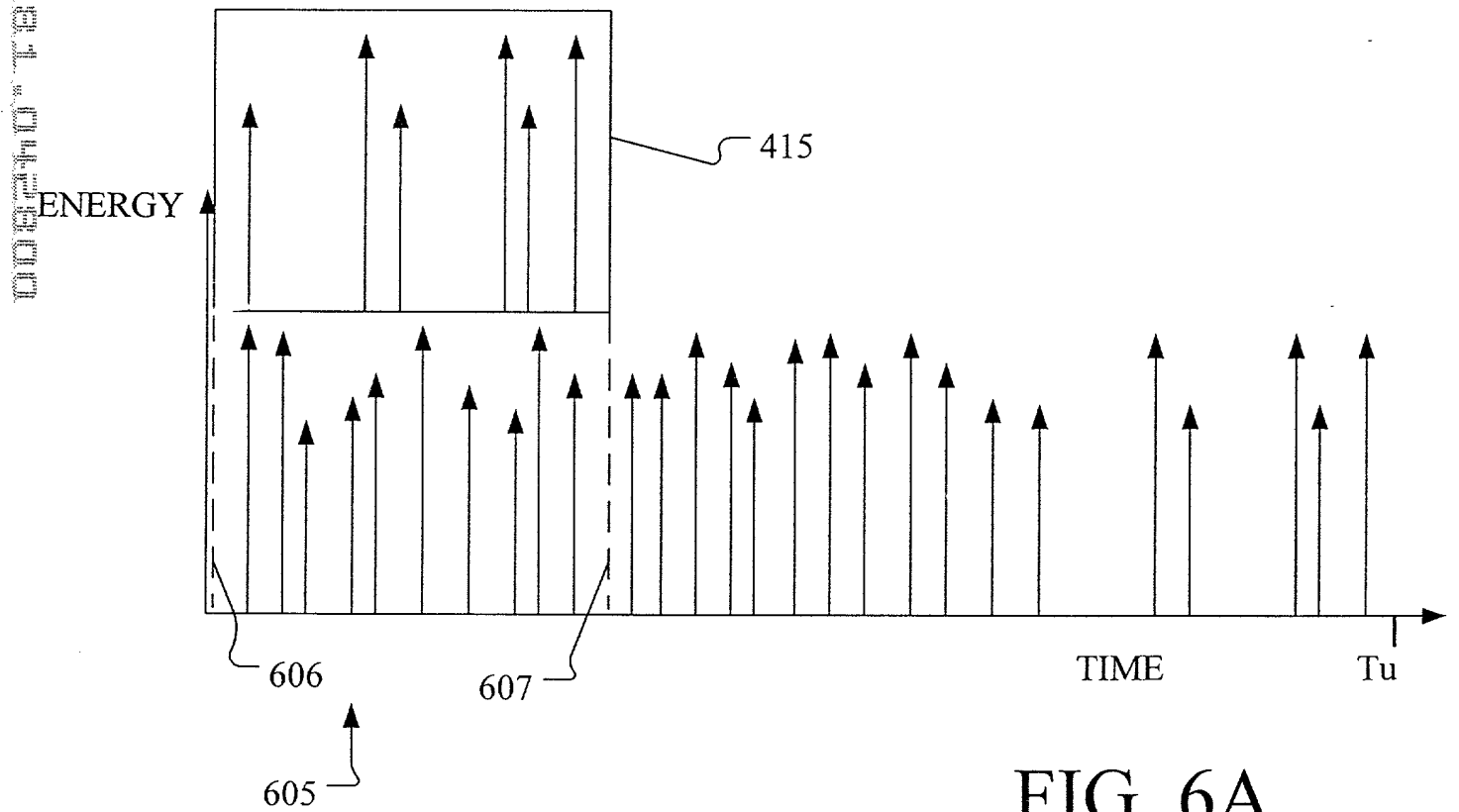


FIG. 6A

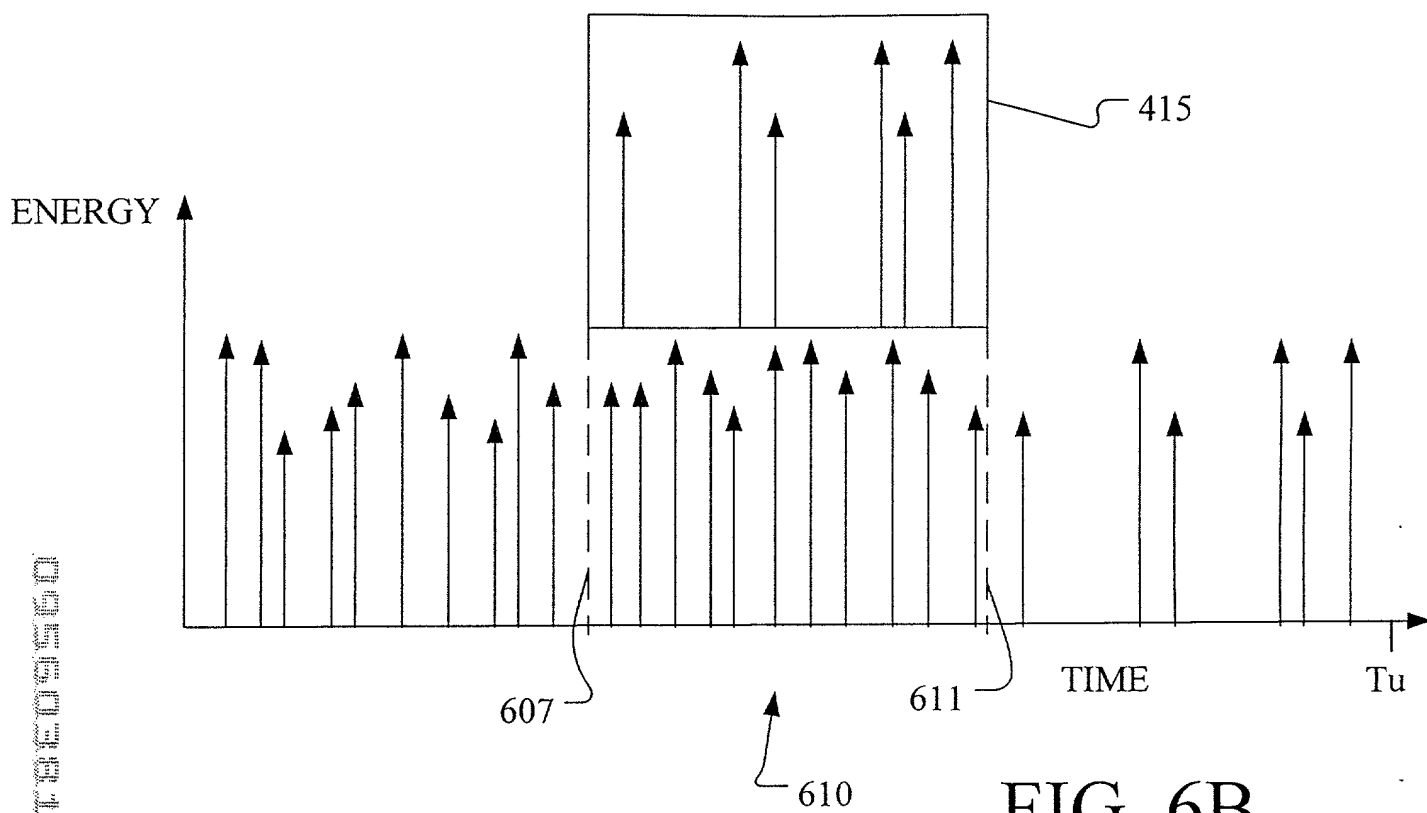


FIG. 6B

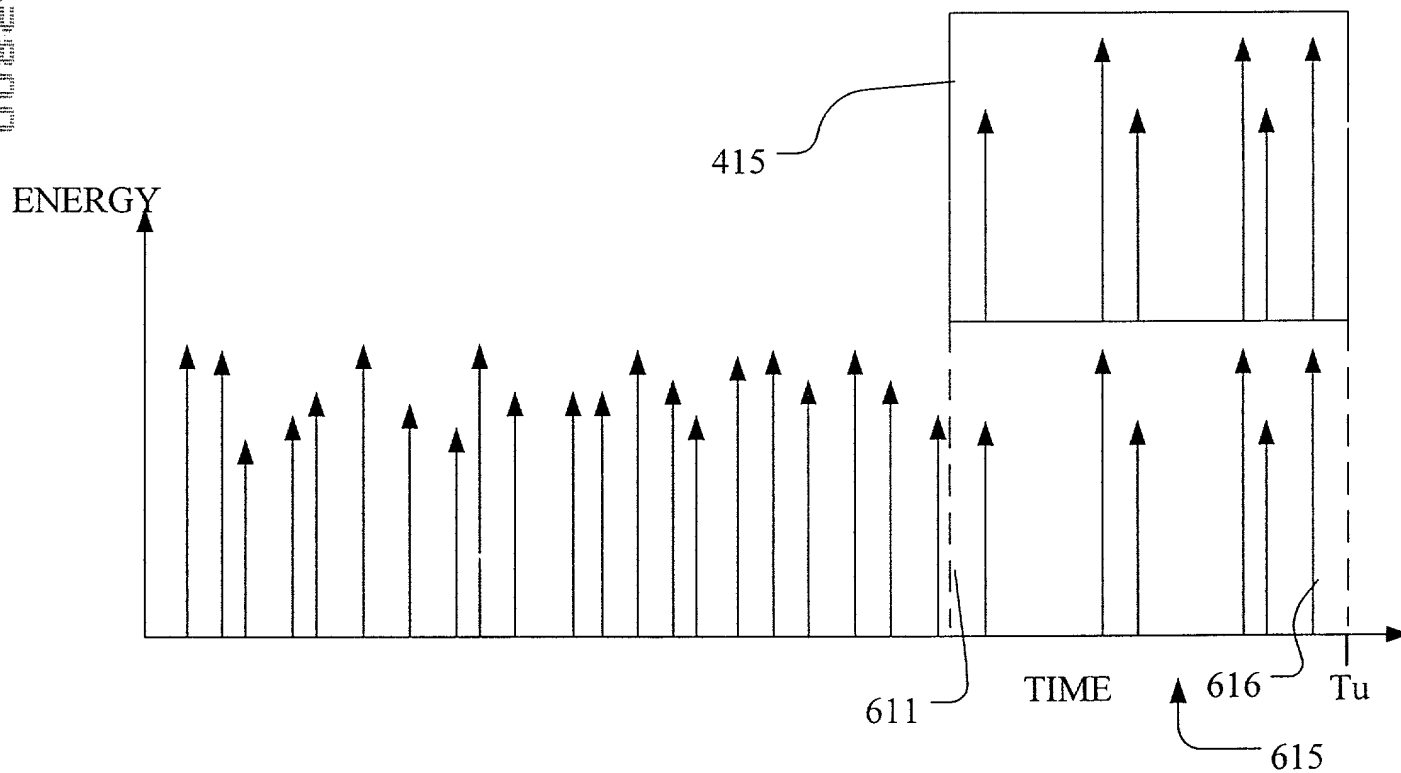


FIG. 6C

DECLARATION FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

Docket #99CR074/KE

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are list below) of the subject matter which is claimed and for which a patent is sought on the **Synchronization Technique For Spread Spectrum Frequency Hopped Data Links And Radios Using The Same**, the specification of which

(check one) ☒ is attached hereto.
☐ was filed on _____ as
☐ Application Serial No. _____
 and was amended on _____.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s) None

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial Number)	(Filing Date)	(Status -patented, pending, abandoned)

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: Kyle Eppele, Reg. #34,155, James P. O'Shaughnessy, Reg. #27,667, John J. Horn, Reg. # 28,803, John M. Miller, Reg. # 38,560, John J. Deinken, Reg. #28,406, William R. Walbrun, Reg. # 37,464, and Nathan O. Jensen, Reg. #41,460.

Address all telephone calls to Kyle Eppele at telephone no. (319) 295-8280

Address all communications to ROCKWELL COLLINS, INC.
Attention: Kyle Eppele M/S 124-323
400 Collins Rd. NE
Cedar Rapids, Iowa 52498

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor Stephen M. Clark
 Inventor's Signature Stephen M. Clark Date 4/28/00
 Residence Marion, Iowa 52302 Citizenship USA
 Post Office Address 2610 Pheasant Ridge Ct
Marion, IA 52302

Full name of second joint inventor, if any Terry J. Golubiewski
 Second Inventor's Signature Terry J. Golubiewski Date 4-28-00
 Residence Cedar Rapids, Iowa 52402 Citizenship USA
 Post Office Address 4535 Twin Pine Drive NE
Cedar Rapids, IA 52402

Full name of third joint inventor, if any Scott J.F. Zogg
 Third Inventor's Signature Scott J.F. Zogg Date 4/28/00
 Residence Cedar Rapids, Iowa 52411 Citizenship USA
 Post Office Address 2765 Tower Dr
Cedar Rapids, IA 52411